AERMOD IMPLEMENTATION GUIDE

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PREFACE

This document provides information on the recommended use of AERMOD for particular applications. The following recommendations augment the use of experience and judgment in the proper application of dispersion models. Advanced coordination with reviewing authorities, including the development of modeling protocols, is recommended for regulatory applications of AERMOD.

ACKNOWLEDGMENTS

The AERMOD Implementation Guide has been developed through the collaborative efforts of EPA OAQPS, EPA Regional Office, State and local agency dispersion modelers, through the activities of the AERMOD Implementation Workgroup. The efforts of all contributors are gratefully acknowledged.

CONTENTS

1.0 WHAT'S NEW IN THIS DOCUMENT

Revisions dated October 19, 2007:

This is the first update to the AERMOD Implementation Guide since it was first released September 27, 2005. In addition to the changes identified below, the document has been restructured to better accommodate current and future updates.

The following sections have been affected by this revision:

3.1 SELECTING SURFACE CHARACTERISTICS

> This section includes a note regarding the pending release of the draft AERSURFACE tool and pending changes regarding recommended methods for estimating surface characteristics from land use/land cover data.

3.2 SELECTING UPPER AIR SOUNDING LEVELS

> This section addresses the selection of upper air sounding levels for processing in AERMET.

5.1 URBAN/RURAL DETERMINATION

> This section includes recommendations for determining whether a source(s) should be modeled as urban or rural.

5.2 SELECTING POPULATION DATA FOR AERMOD'S URBAN MODE

> This section includes additional discussion regarding use of population density to determine the urban population for input to AERMOD.

5.3 OPTIONAL URBAN ROUGHNESS LENGTH – URBANOPT KEYWORD

> This section addresses the optional surface roughness parameter under the AERMOD urban option.

2.0 DOCUMENT BACKGROUND AND PURPOSE

2.1 BACKGROUND (10/19/07)

In April 2005, the AERMOD Implementation Workgroup (AIWG) was formed in anticipation of AERMOD's promulgation as a replacement for the Industrial Source Complex (ISCST3) model. AERMOD fully replaced ISCST3 as the regulatory model on December 9, 2006[1], after a one-year grandfather period. The primary purpose for forming the AIWG was to develop a comprehensive approach for dealing with implementation issues for which guidance is needed. A result of this initial AIWG was the publication of the first version of the AERMOD Implementation Guide on September 27, 2005.

In 2007, a new AIWG was formed as a standing workgroup to provide support to EPA's Office of Air Quality Planning and Standards (OAQPS). This document represents the combined efforts of AIWG and OAQPS in relation to the implementation of the AERMOD regulatory model.

2.2 PURPOSE (10/19/07)

This document provides information on the recommended use of AERMOD for particular applications. Topics are organized based on implementation issues, with additional information as appropriate on whether they impact the modules of the AERMOD modeling system (AERMOD, AERMET, and AERMAP) or related programs (AERSURFACE, AERSCREEN, and BPIPPRM). The document contains a section which highlights changes from the previous version. This is located in Section 1 of the document for use as a quick reference. Each section is also identified with the date (mm/dd/yy) that it was added or last updated. Only sections with substantive changes or new recommendations are identified with new revision dates. Revision dates are not updated for sections with only minor edits to clarify the wording or to correct typographical errors.

The recommendations contained within this document represent best use practices as determined by EPA, through the implementation of AIWG. The document is not intended as a replacement of, or even a supplement to the *Guideline on Air Quality Models*[2]. Rather, it is designed to provide consistent, technically sound recommendations to specific issues relevant to the regulatory application of AERMOD. As always, advance cooperation with the reviewing authorities on the application of AERMOD is advisable. Modeling protocols should be developed, and agreed upon, in advance of any modeling activity.

3.0 METEOROLOGICAL DATA AND PROCESSING

3.1 SELECTING SURFACE CHARACTERISTICS (10/19/07)

> NOTE: *A draft version of the AERSURFACE tool, designed to assist users with estimating surface characteristics for input to AERMET, is being finalized for release. The methodology implemented in the current draft version of AERSURFACE differs in some respects from the procedures described in this section and in Section 5.4 of the AERMET User's Guide (EPA-454/B-03-002). More details regarding the methodology implemented in AERSURFACE will be provided with the release of the AERSURFACE program and documentation. Appropriate changes to the AERMOD Implementation Guide and AERMET User's Guide will also be released at that time. Users are encouraged to check regularly for these updates. (10/19/07)*

If you are using AERMET to prepare the meteorological data for AERMOD, you must input three surface characteristics, the surface roughness $\{z_o\}$, the albedo $\{r\}$, and the Bowen ratio $\{B_o\}$. When using National Weather Service (NWS) data for AERMOD, data representativeness can be thought of in terms of constructing realistic PBL similarity profiles. As such, the determination of representativeness will depend on a comparison of the surface characteristics (i.e., z_o, B_o and r) between the NWS measurement site and the source location, coupled with a determination of the importance of those differences relative to predicted concentrations. The discussion in this section related to NWS data also applies to other sources of non-site-specific data.

The degree to which predicted pollutant concentrations are influenced by surface parameter differences between the application site and the NWS site depends on the nature of the application (i.e., release height, buoyancy, design metric, downwash considerations, etc.). For example, a difference in z_o for one application may translate into an unacceptable difference in the design concentration while for another application, the same difference in z_o may lead to an insignificant difference in design concentration. If the reviewing agency is uncertain as to the representativeness of an NWS site, a site-specific sensitivity analysis may be needed in order to quantify, in terms of expected changes in the design concentration, the significance of the differences in each of the surface characteristics.

If the nearest NWS meteorological site's surface characteristics are determined to NOT be representative of the application site, it may be possible that another nearby NWS site may be representative of both weather parameters and surface characteristics. Failing that, it is likely that site-specific meteorological data will be required.

In defining sectors for surface characteristics, the user should specify a sector no smaller than a 30-degree arc. The expected wind direction variability over the course of an hour, as well as the encroachment of characteristics from the adjacent sectors with travel time, makes it hard to preserve the integrity of very narrow sector characteristics. Thus, the user should apply a weighted average of surface characteristics by surface area within each sector for 3 kilometers upwind. Further information on the definition of sectors for surface parameters is provided in the AERMET user's guide.

Here are some suggestions for determining surface characteristics for specific cases:

3.1.1 Rural sources using rural NWS meteorological data (09/27/05)

Having found an NWS site to be representative of the application site, the values of the surface parameters at the meteorological site should, in general, be used for constructing AERMOD's meteorological profiles. However, as discussed below, it may be acceptable to use regional or application site values for B_o and r. Conversely, for z_o it is generally preferred to use values from the meteorological site since the magnitude of the measured wind speed is intrinsically linked to surface roughness; that is, the higher the surface roughness the greater the mechanical turbulence and the lower the wind speed for a given amount of kinetic energy in the approach flow.

In general, for low-level releases, the effects of local differences in z_o are expected to be considerably more significant than similar differences in either B_o or r. Since the albedo and Bowen ratio are used to determine how much of the incoming radiation is converted to sensible heat flux, they are not a strong influence on the measured winds and for many AERMOD applications, can, in general, be considered more regionally representative. However, as indicated above, this is not the case for z_o. The roughness length directly affects the profiling of the measured wind speed and therefore should generally be associated with the area surrounding the meteorological site.

3.1.2 Urban sources using rural NWS meteorological data (09/27/05)

When modeling an urban source, the urban algorithms in AERMOD are designed to perturb the characteristics of the flow as measured from an adjacent rural area. Therefore, a rural NWS meteorological site that is being used for an urban source should be representative of the rural area that is adjacent to the urban area in which the source is located and must pass the representativeness tests described earlier. Then, the values of the surface parameters (z_o, B_o and r) from the rural meteorological site location can be used for constructing meteorological profiles that are appropriate for the urban source location. This is accomplished by including the "URBANOPT" and the "URBANSRC" keywords in the AERMOD control file.

3.1.3 Urban sources using urban NWS meteorological data (09/27/05)

Most airports are located far enough away from the urban center to be considered rural settings. However, for NWS stations located within the urban area, the basic approach for choosing surface characteristics is similar to that used for rural applications using rural NWS data. That is, values for the surface parameters (z_o, B_o and r) should be taken from the area surrounding the NWS site. However, since profiles constructed from the urban surface measurements will not fully reflect the actual turbulence or the expected development of a nighttime urban mixing height, the user will also need to select AERMOD's URBAN option.

3.1.4 Urban sources using urban site-specific meteorological data (09/27/05)

In most cases site-specific data collected within the urban area should be treated in a manner similar to urban NWS data. That is, the surface characteristics should be selected from the meteorological site and AERMOD's urban options should be applied. Furthermore, in order to avoid double counting the effects of the urban heat island, site-specific measured turbulence data should not be used when applying AERMOD's urban option. However, if the site-specific data is of high enough quality and extent, then it may be possible on a case-by-case basis to apply AERMOD without use of the URBAN option. In order to apply AERMOD in an urban setting without selecting its urban option the meteorological data used must be sufficient to fully define the profiles of wind, temperature and turbulence, as well as including estimates of the urban nighttime mixing height.

3.2 SELECTING UPPER AIR SOUNDING LEVELS (10/19/07)

The AERMET meteorological processor requires full upper air soundings (radiosonde data) representing the vertical potential temperature profile near sunrise in order to calculate convective mixing heights. For AERMOD applications within the U.S., the early morning sounding, nominally collected at 12Z (or UTC/GMT), is typically used for this purpose. Upper air soundings can be obtained from the Radiosonde Data of North America CDs for the period 1946 through 1997, which are available for purchase from the National Climatic Data Center (NCDC). Upper air soundings for the period 1994 to the present are also available for free download from the Radiosonde Database Access website (http://raob.fsl.noaa.gov/).

Both of these sources of upper air data offer the following three options for specifying which levels of upper air data to extract:

1) all levels,
2) mandatory and significant levels, or
3) mandatory levels only.

Options 1 and 2 are both acceptable and should provide equivalent results when processed through AERMET. The use of mandatory levels only, Option 3, will not provide an adequate characterization of the potential temperature profile, and is not acceptable for AERMOD modeling applications.

4.0 TERRAIN DATA AND PROCESSING

4.1 MODELING SOURCES IN GENTLY DOWN-SLOPING TERRAIN (09/27/05)

For all situations in which there is a difference in elevation between the source and receptor, AERMOD simulates the total concentration as the weighted sum of 2 plume states[3]: 1) a horizontal plume state (where the plume's elevation is assumed to be determined by release height and plume rise effects only, and thereby allowing for impingement if terrain rises to the elevation of the plume); and, 2) a terrain-responding plume state (where the plume is assumed to be entirely terrain following).

For cases in which receptor elevations are lower than the base elevation of the source (i.e., receptors that are down-slope of the source), AERMOD will predict concentrations that are less than what would be estimated from an otherwise identical flat terrain situation. Therefore, in the case of gently down-sloping terrain, where expert judgment suggests that the plume is terrain following (e.g., down-slope gravity flow), AERMOD will tend to underestimate concentrations. This situation has been examined for low-level area sources by Sears (2003)[4]. Sears has shown that as terrain down-slope increases the ratio of AERMOD to ISC (which assumes flat terrain in this situation) estimates decreases substantially.

To avoid this situation, it may be reasonable, in the case of gently down-sloping terrain, to assume flat, level terrain, especially for low-level sources. This decision should be made on a case-by-case basis, relying on the modelers experience and knowledge of the surrounding terrain and other factors that affect the air flow in the study area.

4.2 AERMAP DEM ARRAY AND DOMAIN BOUNDARY (09/27/05)

Section 2.1.2 of the AERMAP User's Guide states that the DEM array and domain boundary must include all terrain features that exceed a 10% elevation slope from any given receptor. The 10% slope rule may lead to excessively large domains in areas with considerable terrain features (e.g., fjords, successive mountain ranges, etc). In these situations, the reviewing authority may make a case-by-case determination regarding the domain size needed for AERMAP to determine the critical dividing streamline height for each receptor.

4.3 MANUALLY ENTERING TERRAIN ELEVATIONS IN AERMAP (09/27/05)

AERMAP currently does not have the capability of accepting hand-entered terrain data (xyz data). AERMAP can accept terrain data from DEM files only. Therefore, if DEM data is not available, for a particular application, terrain elevations will need to be entered manually in a form that mimics the DEM data format. Instructions for how to accomplish this can be found on the SCRAM web site http://www.epa.gov/scram001/ in a document titled "On inputting XYZ data into AERMAP."

5.0 URBAN APPLICATIONS

5.1 URBAN/RURAL DETERMINATION (10/19/07)

The URBANOPT keyword on the CO pathway in AERMOD, coupled with the URBANSRC keyword on the SO pathway, should be used to identify sources to be modeled using the urban algorithms in AERMOD. To account for the dispersive nature of the "convective-like" boundary layer that forms during nighttime conditions due to the urban heat island effect, AERMOD enhances the turbulence for urban nighttime conditions over that which is expected in the adjacent rural, stable boundary layer, and also defines an urban boundary layer height to account for limited mixing that may occur under these conditions. The magnitude of the urban heat island effect is driven by the urban-rural temperature difference that develops at night. AERMOD currently uses the population input on the URBANOPT keyword as a surrogate to define the magnitude of this differential heating effect. Details regarding the adjustments in AERMOD for the urban boundary layer are provided in Section 5.8 of *AERMOD: Description of Model Formulation* (EPA-454/R-03-004)[3].

Section 7.2.3 of the *Guideline on Air Quality Models*[2] provides the basis for determining the urban/rural status of a source. For most applications the Land Use Procedure described in Section 7.2.3(c) is sufficient for determining the urban/rural status. However, there may be sources located within an urban area, but located close enough to a body of water or to other non-urban land use categories to result in a predominately rural land use classification within 3 kilometers of the source following that procedure. Users are therefore cautioned against applying the Land Use Procedure on a source-by-source basis, but should also consider the potential for urban heat island influences across the full modeling domain. Furthermore, Section 7.2.3(f) of Appendix W recommends modeling <u>all</u> sources within an ***urban complex*** using the urban option even if some sources may be defined as rural based on the procedures outlined in Section 7.2.3. Such an approach is consistent with the fact that the urban heat island is not a localized effect, but is more regional in character.

Another aspect of the urban/rural determination that may require special consideration on a case-by-case basis relates to tall stacks located within or adjacent to small to moderate size urban areas. In such cases, the stack height, or effective plume height for very buoyant plumes, may extend above the urban boundary layer height. Application of the urban option in AERMOD for these types of sources may artificially limit the plume height. Therefore, use of the urban option may not be appropriate for these sources, since the actual plume is likely to be transported over the urban boundary layer. A proper determination of whether these sources should be modeled separately without the urban option will depend on a comparison of the stack height or effective plume height with the urban boundary layer height. The urban boundary layer height, z_{iuc}, can be calculated from the population input on the URBANOPT keyword, P, based on Equation 104 of the AERMOD formulation document[3]:

$$z_{iuc} = z_{iuo} \left(P/P_0 \right)^{1/4} \qquad (1)$$

where z_{iu0} is the reference height of 400 meters corresponding to the reference population, P_0, of 2,000,000. Exclusion of these elevated sources from application of the urban option must be justified on a case-by-case basis in consultation with the appropriate reviewing authority.

5.2 SELECTING POPULATION DATA FOR AERMOD'S URBAN MODE (10/19/07)

For relatively isolated urban areas, the user may use published census data corresponding to the Metropolitan Statistical Area (MSA) for that location. For urban areas adjacent to or near other urban areas, or part of urban corridors, the user should attempt to identify that part of the urban area that will contribute to the urban heat island plume affecting the source(s). If this approach results in the identification of clearly defined MSAs, then census data may be used as above to determine the appropriate population for input to AERMOD. Use of population based on the Consolidated MSA (CMSA) for applications within urban corridors is not recommended, since this may tend to overstate the urban heat island effect.

For situations where MSAs cannot be clearly identified, the user may determine the extent of the area, including the source(s) of interest, where the population density exceeds 750 people per square kilometer[5]. The combined population within this identified area may then be used for input to the AERMOD model. Users should avoid using a very fine spatial resolution of population density for this purpose as this could result in significant gaps within the urban area due to parks and other unpopulated areas, making it more difficult to define the extent of the urban area. Population densities by census tract should provide adequate resolution in most cases, and may still be finer resolution than desired in some cases. Since census tracts vary in size and shape, another acceptable approach would be to develop gridded estimates of population data based on census block or block group data. In such cases, a grid resolution on the order of 6 kilometers is suggested. Plotting population density with multiple "contour" levels, such as 0-500, 500-750, 750-1000, 1000-1500, etc., may also be beneficial in identifying which areas near the edge of the urban complex to include even though the population density may fall below the 750 threshold. The user should also bear in mind that the urban algorithms in AERMOD are dependent on population to the one-fourth power, and are therefore not highly sensitive to variations in population. Population estimates to two significant figures should be sufficiently accurate for application of AERMOD.

5.3 OPTIONAL URBAN ROUGHNESS LENGTH – URBANOPT KEYWORD (10/19/07)

The URBANOPT keyword on the CO pathway includes an optional parameter to specify the urban surface roughness length. The urban surface roughness parameter is used to define a reference height for purposes of adjusting dispersion for surface and low-level releases to account for the enhanced turbulence associated with the nighttime urban heat island. This optional urban roughness length is <u>not</u> used to adjust for differences in roughness length between the meteorological measurement site, used in processing the meteorological data, and the urban application site. Details regarding the adjustments in AERMOD for the urban boundary layer, including the use of the urban roughness length parameter, are provided in Section 5.8 of *AERMOD: Description of Model Formulation* (EPA-454/R-03-004)[3].

The default value of 1 meter for urban surface roughness length, assumed if the parameter is omitted, is considered appropriate for most applications. Any application of AERMOD that utilizes a value other than 1 meter for the urban roughness length should be considered as a non-regulatory application, and would require appropriate documentation and justification as an alternative model, subject to Section 3.2 of the *Guideline on Air Quality Models*[2]. The use of a value other than 1 meter for the urban surface roughness length will be explicitly treated as a non-DFAULT option in the next update to the AERMOD model.

6.0 SOURCE CHARACTERIZATION

6.1 CAPPED AND HORIZONTAL STACKS (09/27/05)

For capped and horizontal stacks that are NOT subject to building downwash influences a simple screening approach (Model Clearinghouse procedure for ISC) can be applied. This approach uses an effective stack diameter to maintain the flow rate, and hence the buoyancy, of the plume, while suppressing plume momentum by setting the exit velocity to 0.001 m/s. To appropriately account for stack-tip downwash, the user should first apply the non-default option of no stack-tip downwash (i.e., NOSTD keyword). Then, for capped stacks, the stack release height should be reduced by three actual stack diameters to account for the maximum stack-tip downwash adjustment while no adjustment to release height should be made for horizontal releases.

Capped and horizontal stacks that are subject to building downwash should not be modeled using an effective stack diameter to simulate the restriction to vertical flow since the PRIME algorithms use the stack diameter to define the initial plume radius which, in turn, is used to solve conservation laws. The user should input the actual stack diameter and exit temperature but set the exit velocity to a nominally low value, such as 0.001 m/s. This approach will have the desired effect of restricting the vertical flow while avoiding the mass conservation problem inherent with effective diameter approach. The approach suggested here is expected to provide a conservative estimate of impacts. Also, since PRIME does not explicitly consider stack-tip downwash, no adjustments to stack height should be made.

6.2 USE OF AREA SOURCE ALGORITHM IN AERMOD (09/27/05)

Because of issues related to excessive run times and technical issues with model formulation, the approach that AERMOD uses to address plume meander has not been implemented for area sources. As a result, concentration predictions for area sources may be overestimated under very light wind conditions (i.e., $u << 1.0$ m/s). In general, this is not expected to be a problem for meteorological data collected using standard wind instruments since instrument thresholds are generally too high. However, the problem could arise with meteorological data derived from very low threshold instruments, such as sonic anemometers. While not currently accepted for regulatory applications of AERMOD, this problem has also arisen when data from a gridded meteorological model was used to drive AERMOD. Meteorological grid models can at times produce extremely light winds. During such conditions time-averaged plumes tend to spread primarily as a result of low frequency eddy translation rather than eddy diffusion. AERMOD treats this meander effect by estimating the concentration from two limiting states: 1) a coherent plume state that considers lateral diffusive turbulence only (the mean wind direction is well defined) and 2) a random plume state (mean wind direction is poorly defined) that allows the plume to spread uniformly, about the source, in the x-y plane. The final concentration predicted by AERMOD is a weighted sum of these two bounding concentrations. Interpolation between the coherent and random plume concentrations is accomplished by assuming that the total horizontal "energy" is distributed between the wind's mean and turbulent components.

In order to avoid overestimates for area sources during light wind conditions, it is recommended that, where possible, a volume source approximation be used to model area sources. This approach can be applied with confidence for situations in which the receptors are displaced from the source. However, for applications where receptors are located either directly adjacent to, or inside the area source, AERMOD's area source algorithm will need to be used. For these circumstances, caution should be exercised if excessive concentrations are predicted during extremely light wind conditions. On a case-by-case basis, the reviewing authority should decide whether such predictions are unrealistic. One possible remedy would be to treat such hourly predictions as missing data.

It is EPA's intention to correct this problem. A version of AERMOD that includes meander for area sources will be developed as soon as practicable.

7.0 REFERENCES

[1] 40 Federal Register Volume 70, Page 68218.

[2] 40 CFR Part 51 Appendix W.

[3] Cimorelli, A. J., S. G. Perry, A. Venkatram, J. C. Weil, R. J. Paine, R. B. Wilson, R. F. Lee, W. D. Peters, R. W. Brode, and J. O. Paumier, 2004. AERMOD: Description of Model Formulation, EPA-454/R-03-004.

[4] Sears, C., 2003. Letter to Docket No. A-99-05 Availability of Additional Documents Relevant to Anticipated Revisions to Guideline on Air Quality Models Addressing a Preferred General Purpose (flat and complex terrain) Dispersion Model and Other Revisions (Federal Register / Vol. 68, No. 173 / Monday, September 8, 2003).

[5] Irwin, J.S., 1978. Proposed Criteria for Selection of Urban Versus Rural Dispersion Coefficients. (Draft Staff Report), Meteorology and Assessment Division, U.S. Environmental Protection Agency, Research Triangle Park, NC. (Docket No. A-80-46, II-B-8).